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↑ THRUST-VECTOR CONTROL TEST IN  
THE JET PROPULSION LABORATORY  
20-INCH SUPERSONIC WIND TUNNEL

[6-10 May 1963]

[Edward A. Nierengarten]

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November 18, 1963

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## I. INTRODUCTION

Wind-tunnel Test 20-551 was a thrust-vector control test for Section 381 of Jet Propulsion Laboratory (JPL), using a flat-plate model. The purpose of the test was to obtain the pressure and temperature distribution on the flat plate, about an injector. The approximate aerodynamic parameters for the test were Mach No. 2.01, 2.61, 3.26, 3.50, 3.99, and 4.54, with Reynolds No./ft from  $0.60 \times 10^6$  to  $7.20 \times 10^6$ . The test\* variables and ranges were tunnel stagnation pressures from 6.70 to 54.0 psi, gaseous nitrogen injection pressure from 5.0 to 300.0 psi, liquid nitrogen injection pressure from 40.0 to 150 psi.

The model configuration was a flat plate consisting of 95 plate static-pressure ports and 25 plate thermocouples grouped around an injector in the plate surface. Pressures and temperatures were obtained for the flat plate only, using one single injector, and two single opposed injectors.

The test was conducted at JPL from May 6 through 10, 1963, with Section 381 represented by Mr. M. Dowdy.

## II. MODEL DESCRIPTION

The model is shown in Fig. 1 and 2. The model was a flat plate, 18 in. long, 17.5 in. wide, and 0.5 in. thick, with a wedge angle of 22 deg. The model was fabricated from 321 stainless steel and had a 0.020-in. -diam. trip wire located 0.060 in. from the leading edge to increase the boundary-layer turbulence at the injector station.

The flat plate was instrumented with 95 pressure taps and 25 chromel-constantan thermocouples. The pressure taps were closely spaced on the plate centerline and in one quadrant upstream of the injector station.

The thermocouples were located on the plate centerline and one radial from the injector perpendicular to the plate centerline.

The basic type of injector was a single port type with a diameter of 0.100 in. and a length-to-diameter ratio of one.

A variation from this basic type was a double port injector which employed two impinging jets to atomize the injectant.

The double port injector was not used for gaseous runs. The injector was 7 in. from the plate leading edge.

\*The symbols used in this Report are defined in the Nomenclature.

### III. WIND TUNNEL AND INSTRUMENTATION

Reference 1 describes the construction and operating conditions of the 20-in. supersonic wind tunnel. The wind tunnel has a nominal test-section size of 20 in. square, a Mach range from 1.3 to 5.0, a flexible-plate nozzle, and operates with continuous flow. Table 1 presents representative values of the test-section flow parameters for the Mach numbers at which this test was conducted.

Plate pressures were recorded by an automatic-switching system which permits a single transducer to convert all the pressures to a digitized signal.

Plate temperatures were recorded by an automatic-switching system which converted all thermocouple outputs to a digitized signal.

Plenum temperatures were read on a Brown readout in millivolts and key punched into the main data scan.

Plenum pressures were recorded on a single transducer which converted the pressures to a digitized signal.

Flow-rate measurements were made with Spaco Turbine Model R-3/8-35 flow meter which permitted all flow rates to be converted to a digitized signal and recorded during the main data scan.

To obtain additional information about the induced shock system, injectant shape, and the size of the separated region upstream of the injector, schlieren and shadowgraph pictures were taken for each run/point. High-speed motion pictures were taken with a Milliken camera at 500 frames/sec for a few points.

### IV. TEST PROCEDURE

Test data (Ref. 2) consisted of temperature and pressure values at the desired location on the flat plate about the injector. Prior to the injection of fluid over the flat plate, tunnel total pressure and Mach number were set at the desired values. The fluid, either liquid or gaseous nitrogen, was then injected over the plate. When the conditions of the injectant as measured in the plenum chamber were those desired, a temperature and pressure scan of the plate thermocouples and pressure ports, respectively, was taken.

A few data points were obtained for similar tunnel conditions, using single- and double-port injectors.

## V. RESULTS

Results of this test consist of temperature and pressure values at the desired position on the flat plate.

These results have been plotted by Section 381. Typical of the results are the pressure plots for a single injector, shown in Fig. 3 and 4. Pressure ratios ( $P/P_s$ ) are plotted against distance forward and aft of the injector, using injectants of liquid and gaseous nitrogen, respectively.

The running conditions ( $M$  and  $P_t$ ) were held constant for each injectant.

Figures 5 and 6 are the shadowgraph photographs of the condition presented in Fig. 3 and 4, respectively.

Similar shadowgraphs and a number of schlieren photographs were made at desired points throughout the test.

## NOMENCLATURE

Symbols

|                |                                    |
|----------------|------------------------------------|
| M              | free-stream Mach number            |
| P              | plate static pressure (psia)       |
| P <sub>j</sub> | injection pressure (psia)          |
| P <sub>s</sub> | free-stream static pressure (psia) |
| P <sub>t</sub> | free-stream total pressure (psia)  |
| Rey            | Reynolds number per foot           |

REFERENCES

1. Jet Propulsion Laboratory, California Institute of Technology. Wind-Tunnel Facilities at the Jet Propulsion Laboratory, Wind-Tunnel Staff. Pasadena, Calif., JPL, April 18, 1961. (Technical Release No. 34-257)  
UNCLASSIFIED
2. Jet Propulsion Laboratory, California Institute of Technology. Standard Data-Reduction Procedures for use in the JPL Wind Tunnels. Pasadena, Calif., JPL, June 8, 1962. (Internal Memorandum JPL WT G-T14)  
UNCLASSIFIED



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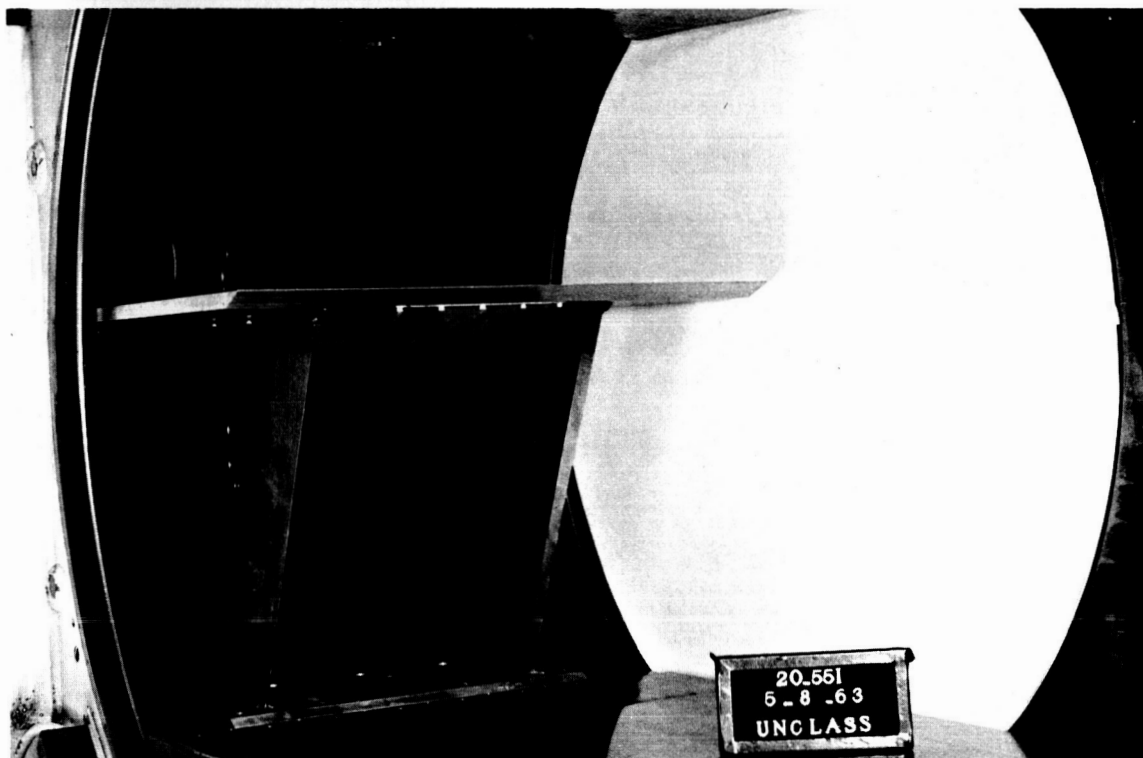
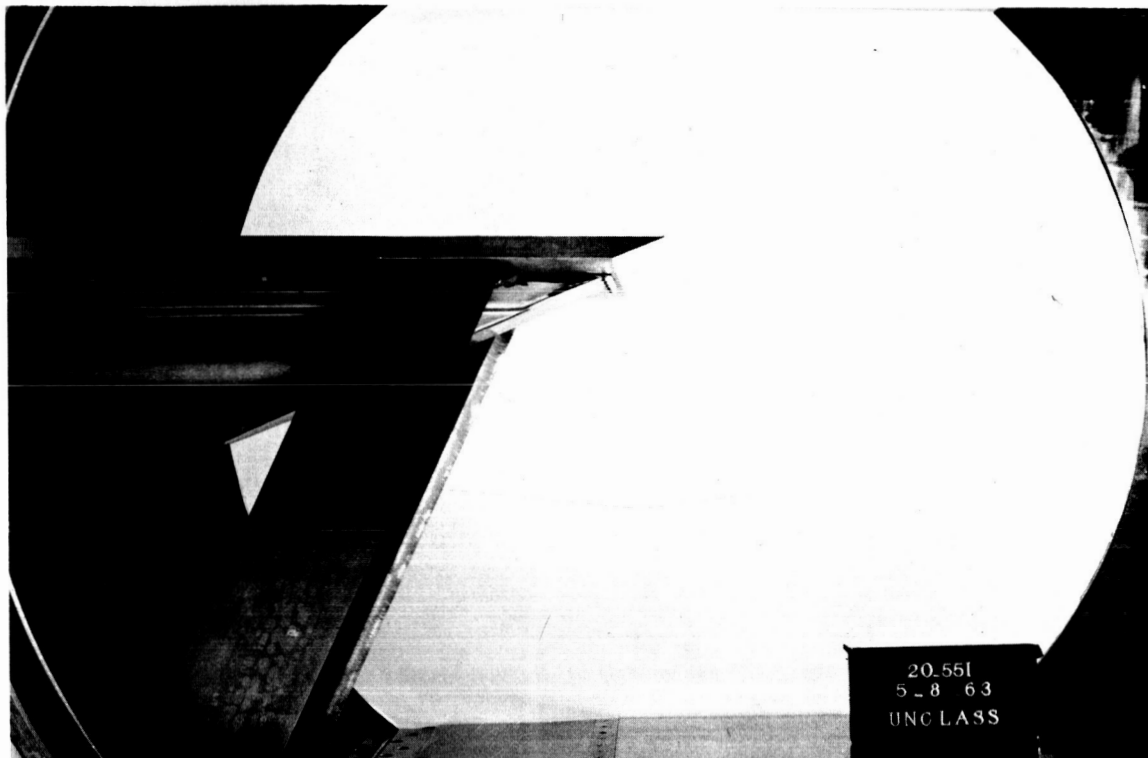
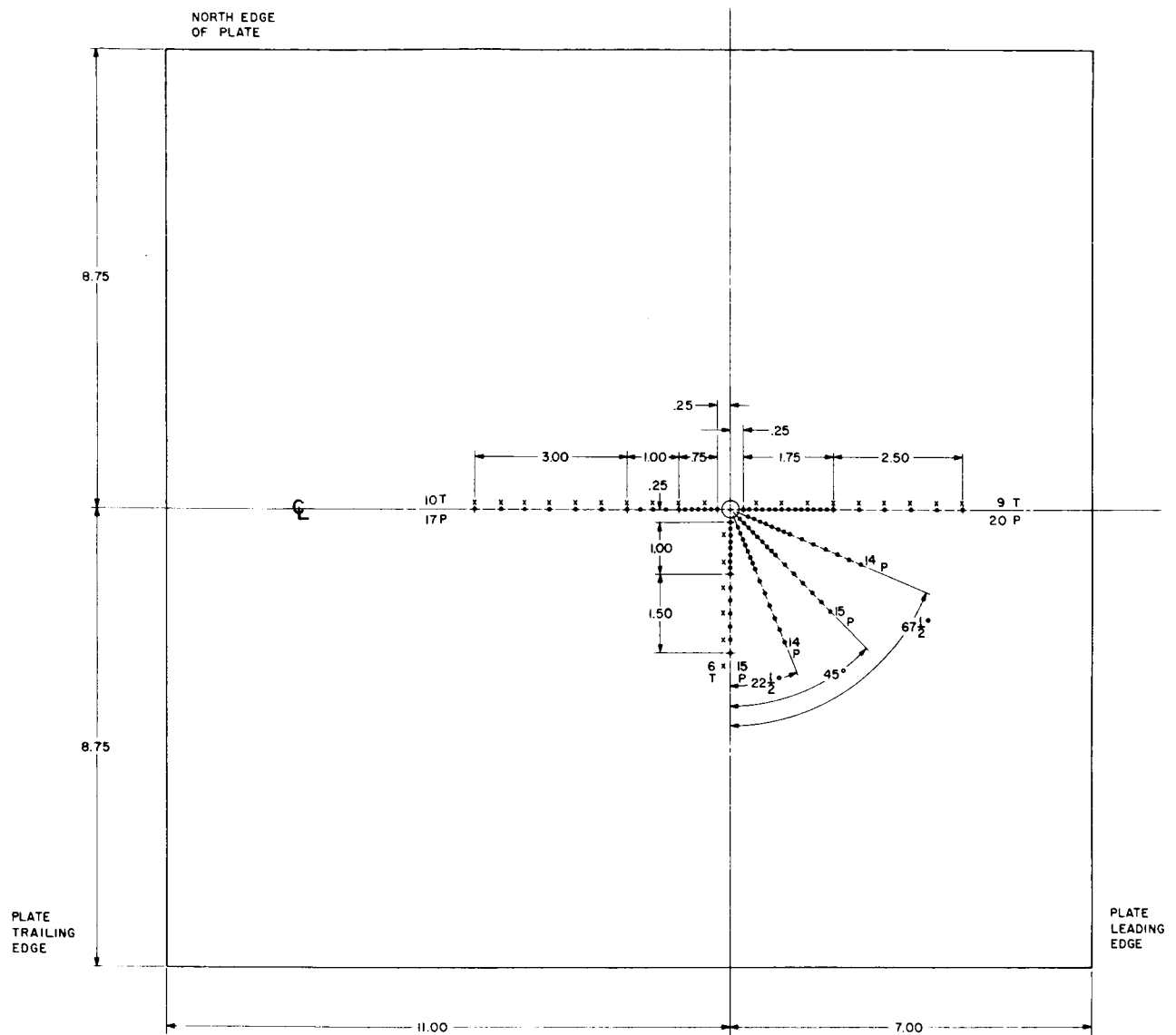


Fig. 1. Installation of model in 20-in. tunnel



(T) THERMOCOUPLE (x)

(P) PRESSURE TAPS (.)

⊕ INJECTOR LOCATION

DIMENSIONS IN INCHES

Fig. 2. Pressure tap and thermocouple locations on TV C flat plate model

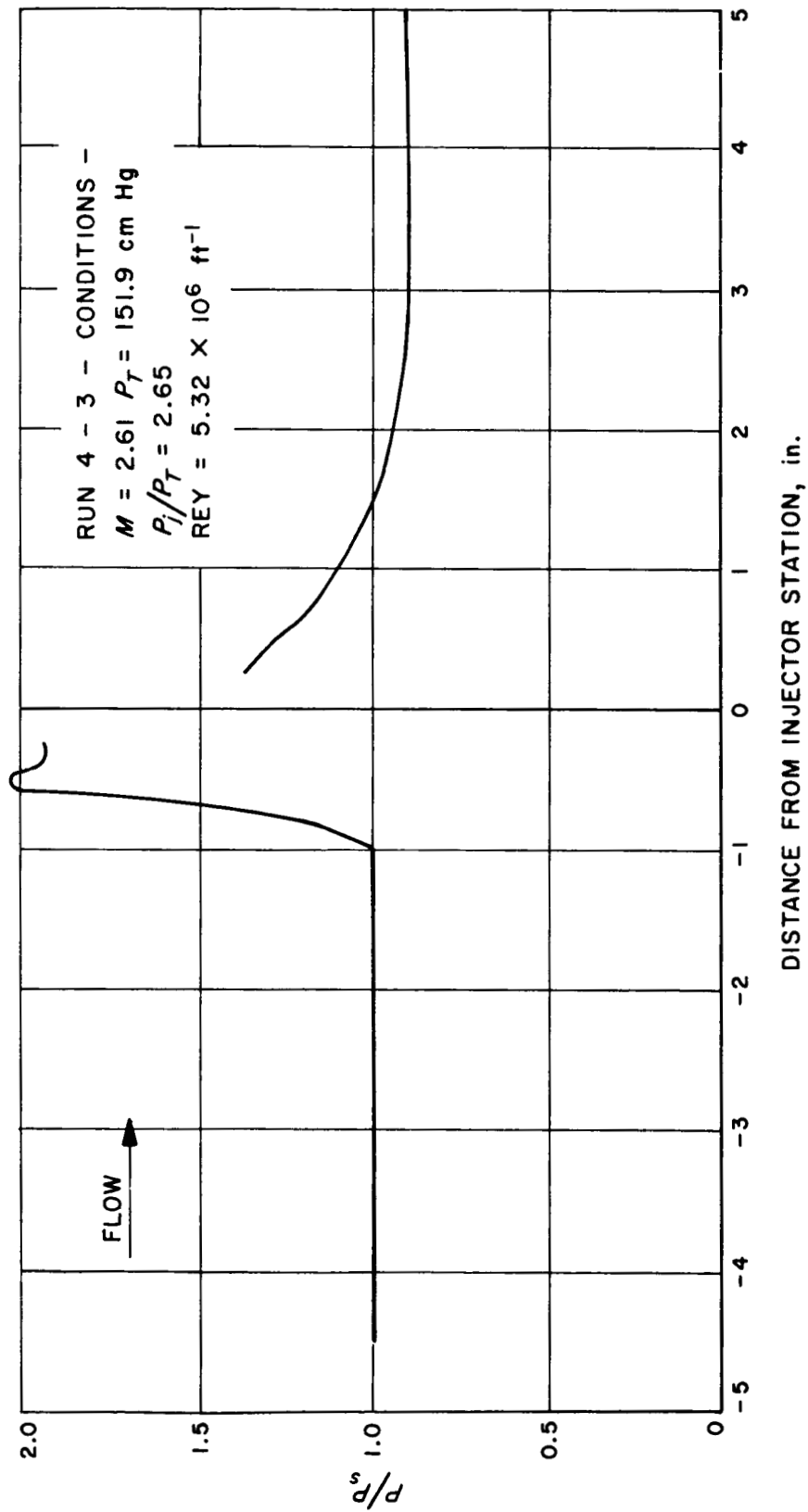


Fig. 3. Centerline pressure distribution for liquid nitrogen injection

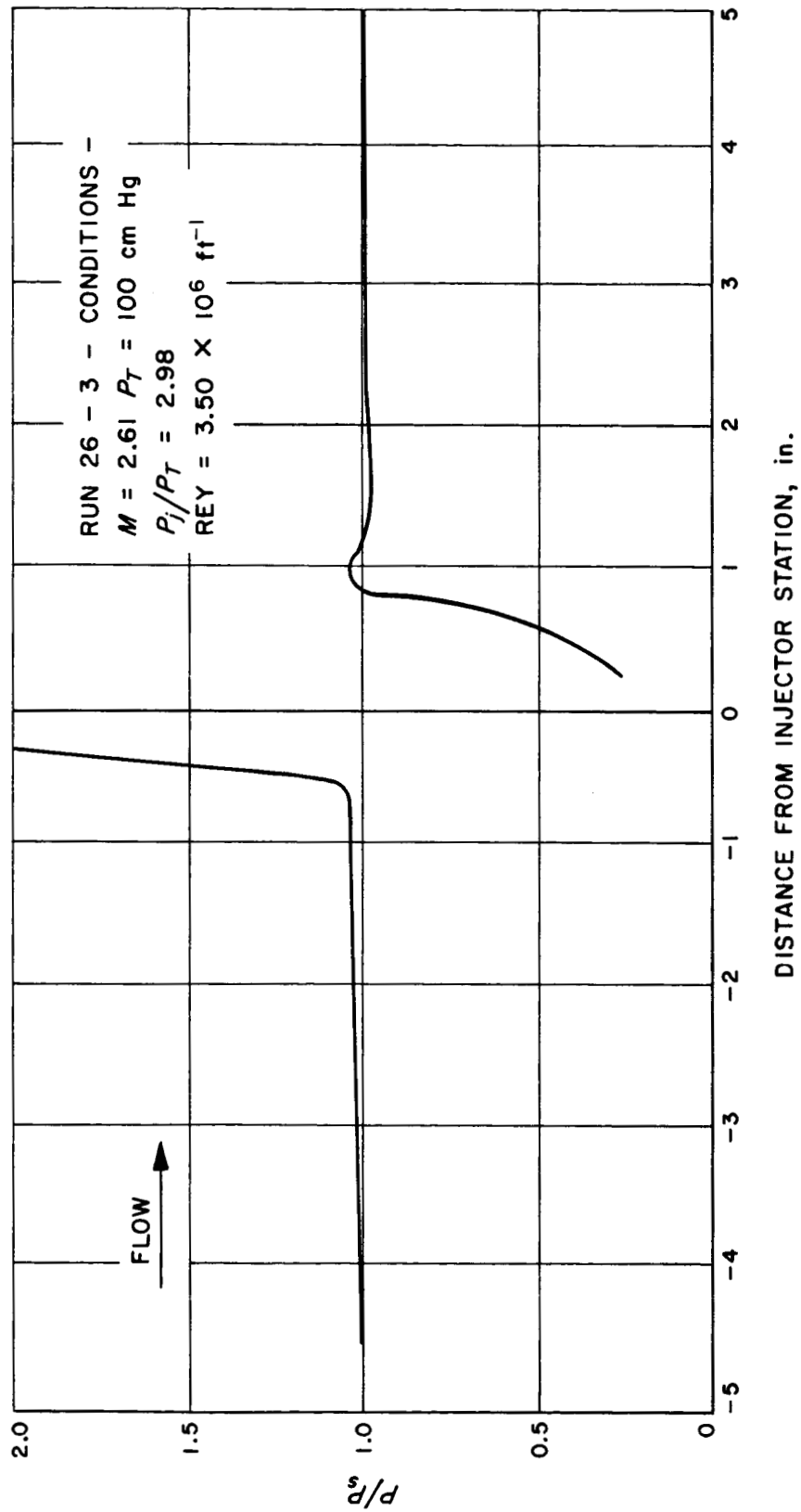


Fig. 4. Centerline pressure distribution for gaseous nitrogen injection

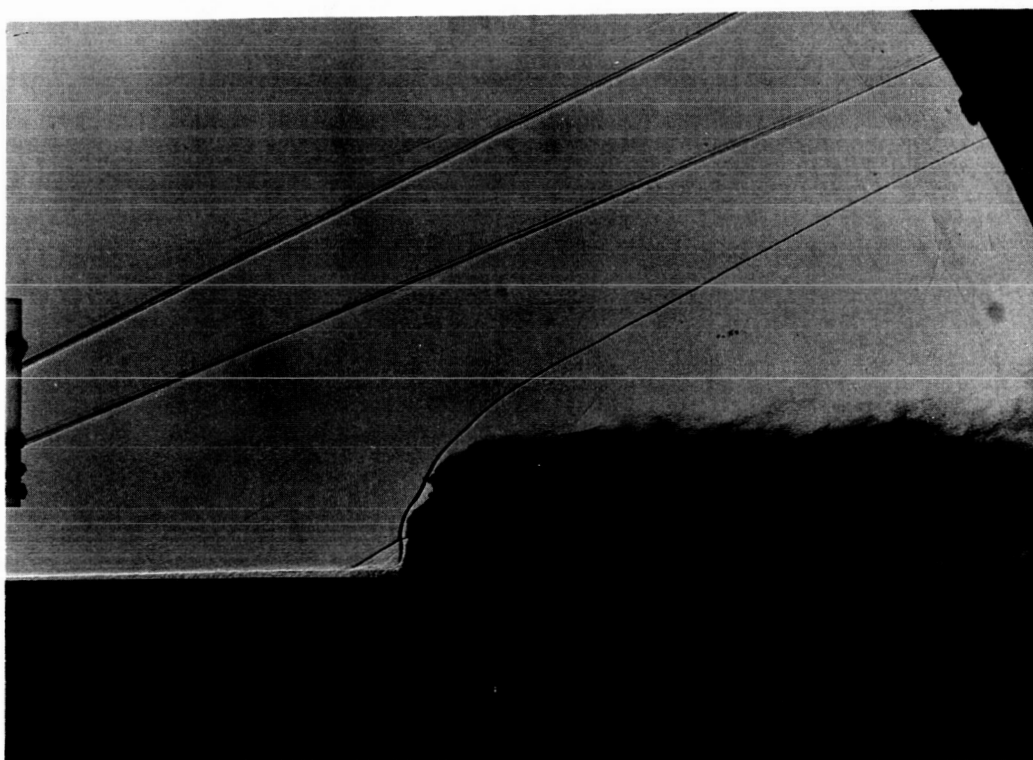


Fig. 5. Shadowgraph of condition in Fig. 3

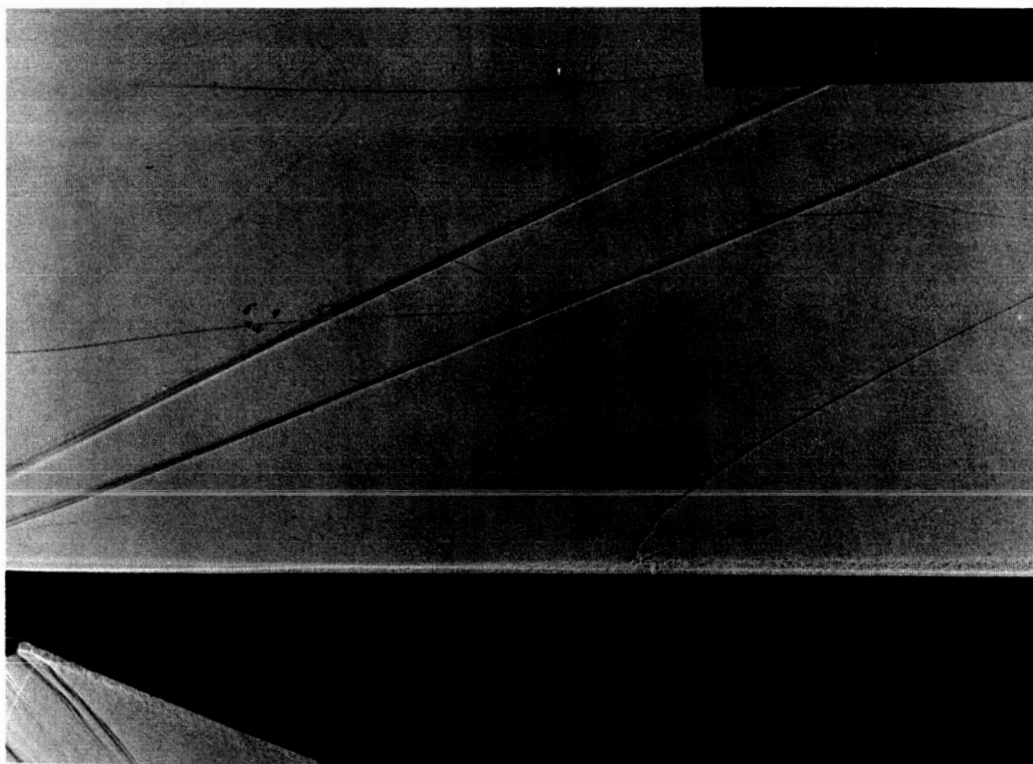


Fig. 6. Shadowgraph of condition in Fig. 4